

5.8.4 Fuel Cells

Fuel cells generate electricity by converting chemical energy into electrical power with few moving parts. Power generation by means of fuel cells is a rapidly emerging technology that provides electricity with high efficiency and little noise. Fuel cells produce no noxious gases that produce acid rain, no particulate pollutants that foul the air, no unburned hydrocarbons during normal operation, and proportionately less carbon dioxide (CO₂) than other, less efficient technologies. Fuel cells provide the opportunity to make the transition from fossil fuels, such as natural gas, methane, and liquid hydrocarbons, to what many consider to be the fuel of the future: hydrogen.

Opportunities

At costs up to \$3,000 to \$4,000 per kW, fuel cells are not for everybody. While DOD and others estimate that the installed cost of a fuel cell will have to drop to \$1,500 per kW before they will be widely used for most applications, they are already cost-effective in situations where very clean power and reliable backup energy supplies are essential. Fuel cells generate cleaner power than is generally available from the utility grid, so facilities with equipment that is sensitive to current and voltage variations can use fuel cells effectively. Hospitals, data centers, and other mission-critical facilities can obtain fuel cells to provide emergency power and then use them to meet a portion of their everyday base load as well. Remote sites without access to the utility grid are also good candidates for fuel cells. Facilities that can make effective use of waste heat can use that free energy to help offset the devices' higher cost.

Technical Information

Fuel cells are electrochemical engines that convert the chemical energy of a fuel and an oxidant—hydrogen and oxygen—directly into electricity. The oxygen used in the fuel cell is atmospheric oxygen, and the hydrogen is either elemental hydrogen or hydrogen extracted from hydrocarbon fuels using a device called a *reformer*. Water is the only significant by-product of a fuel cell's operation. Because nearly all fuel cells in use or under development today rely on hydrocarbon fuels as their source of hydrogen, however, CO₂ and other air pollutants are emitted from the reformer.

The fuel cell's principal components are catalytically activated electrodes for the fuel (anode), the oxidant (cathode), and an electrolyte to conduct ions between the two electrodes. Because the operating conditions of the fuel cell are largely determined by the electrolyte, fuel cells are classified by the type of electrolyte.

Four leading fuel cell technologies are being developed at present:

Phosphoric acid fuel cells (PAFC) have an acid electrolyte and are the most highly developed fuel cells. These operate at relatively low temperatures, around 400°F (200°C), are commercially available, and have thermal output that can be used in cogeneration applications. DOD has been testing 200-kW PAFCs at various facilities since 1993, with generally positive results (see box, next page). The first 1-MW system is currently installed and being tested at a U.S. Postal Service mail distribution center in Anchorage, Alaska (see photograph).

Proton exchange membrane (PEM) fuel cells are well suited to residential, light commercial, and mobile applications requiring relatively compact power systems. The electrochemistry of PEM fuel cells is similar to that of phosphoric acid fuel cells. They operate in the same pressure range but at a much lower temperature, about 175°F (80°C). Their very low thermal and noise signatures may make them especially useful for replacing military generator sets.

Fuel cells using a **molten carbonate** (MCFC) electrolyte are relatively high-temperature units, operating at higher than 1100°F (600°C). Current MCFCs are being designed for applications on the order of 250 kW to 5 MW. The high-temperature exhaust gases can be used in a combined-cycle (cogeneration) system, creating an overall efficiency of about 80%.

Solid oxide (SOFC) electrolyte fuel cells are also high-temperature devices, operating at 1100 to 1800°F (600 to 1000°C). At these temperatures, a natural gas-powered fuel cell does not require a reformer. The solid construction of the SOFC fuel cell prevents some of the corrosion problems of liquid-electrolyte fuel cells. SOFC cogeneration power systems are expected to provide electric power at efficiencies close to 50% and useful steam or hot water at about 40% of rated power, raising the overall effectiveness of the system. A variety of 20- to 125-kW SOFC units have been tested, and units up to 1 MW are planned for preproduction release.

The U.S. Postal Service distribution center in Anchorage, Alaska, is powered by five 200-kW fuel cells as part of the DOD Fuel Cell Demonstration Program.



Source: U.S. Postal Service

Fuel cells are inherently less polluting than conventional fossil-fuel technologies and are more efficient in producing electricity. They produce almost no harmful air or water emissions. The principal by-product is water. However, PAFC, MCFC, and PEM fuel cells have inherent maintenance problems related to water issues. Make-up water supply is required, and—depending on the mineral content—a water treatment system may also be required.

The footprint of a 200-kW PAFC unit is about 200 ft² (20 m²), while the footprint of a 2.85-MW MCFC plant is about 4,500 ft² (450 m²). For many types of fuel cell power plants, stack and fuel processor units must be replaced every 5 to 10 years, requiring a shutdown of several days. Current cost estimates for this are up to half the cost of the fuel cell plant.

References

Fuel Cells for Buildings program; U.S. Department of Energy; www.pnl.gov/fuelcells/.

Wilson, Alex, and Nadav Malin, "Fuel Cells: A Primer on the Coming Hydrogen Economy," *Environmental Building News*, Vol. 8, No. 4, April 1999; Building-Green, Inc., Brattleboro, VT; (800) 861-0954; www.BuildingGreen.com.

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DOD Fuel Cell Demonstration Program:

Since Fiscal Years 1993 and 1994, the U.S. Army's Construction Engineering Research Laboratory has overseen the installation and operation of 30 PAFC fuel cells made by ONSI Corporation at facilities across the nation. Installation and maintenance were included in the contract, thus providing an opportunity for ONSI to learn how its units work in the field. This process has led to several refinements to ONSI's standard PA25 fuel cell.

As of April 1, 2000, the 30 fuel cells had generated a total of 95,000 MWh of electricity and provided 181×10^9 Btu in thermal energy. The displaced cost for this energy is \$3.8 million. Avoided air emissions include 182 tons of nitrous oxides, 390 tons of sulfur oxides, and 15 tons of carbon monoxide. DOD is considering following this program with tests of several other fuel cell technologies.